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ABSTRACT

The concepts of cognitive development and objectivity are explored preparatory to a discussion of a suitable theory of development to be used as the foundation for developmentally-based standardized tests. It is hypothesized that Piagetian theory is the most appropriate basis for such tests and two possible approaches for constructing Piagetian-based standardized instruments are presented. It is concluded that since the logical operations approach eliminates two of the three disadvantages of the content conversion approach, it is a more viable means of attacking the problem. A discussion of item construction, scoring and interpretation, validation, and the effects of the use of a Piagetian-based standardized test follow. Examples are given of items in which it is possible to analyze error patterns in order to observe qualitative developmental changes. Emphasis is on the change from concrete to formal operations. Items are derived from Piaget's work by using his scheme of logical operations rather than merely converting the content to a test format. The validity of scores is checked through evaluation of the child's explanation of his responses, the most mature responses exhibiting stable and generalized concept formation. Implications for teacher education and curriculum planning are suggested. (Author/CTM)

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Standardized Tests Based on Developmental Theory¹

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Abstract

The concepts of cognitive development and standardization are explored preparatory to a discussion of a suitable theory of development to be used as the foundation for developmentally-based standardized tests. It is hypothesized that Piagetian theory is the most appropriate basis for such tests and two possible approaches for constructing Piagetian-based standardized instruments are presented. It is concluded that since the logical operations approach eliminates two of the three disadvantages of the content conversion approach, it is a more viable means of attacking the problem. A discussion of item construction, scoring and interpretation, validation, and the effects of the use of a Piagetian-based standardized test follow.

Standardized Tests Based on Developmental Theory

In proposing developmentally-based standardized tests the concepts of cognitive development and standardization must first be defined. For the purposes of this paper development is considered to be "the temporal transformation of structures in the double sense of differentiation of substructures and their integration into totalities" (Piaget, 1967/1971, p. 71); that is, it is a description and/or explanation of qualitative intra-individual changes through time. Assessing these changes requires that individual test items be constructed, and the responses to the items be evaluated, in such a way that the emphasis is placed on the differences between the competencies represented by the items and thus on the behavioral changes represented by those differences.

The concept of standardization may be approached from a variety of perspectives. Basically, it refers to (1) uniform procedures for administering a test and/or (2) uniform procedures for scoring the responses to individual test items. That is, regardless of who is administering the test, it will be administered in the same way to all testees; and regardless of who is scoring an item each response will be scored the same way.

Developmentally based standardized tests may be of two types: paper and pencil or non-paper and pencil tests. The remaining discussion will focus on written tests since the procedures of administration and scoring can be more easily objectified and consequently standardized.

Given the orientation that developmentally-based standardized tests should provide information on the qualitative changes within individual

children through time, both in general and in various content areas, what theory of development is most appropriate as a theoretical foundation for such a series of tests? The choice of a theory should be governed by three considerations: First, the theoretical focus should be on the development of competencies; second, the description of development must be relatively clear and detailed so that the description can be operationalized into some standardized form; and, finally, the competencies described must have direct relevance to content presented in schools. Using the aforementioned criteria and the basic definition of cognitive development underlying this paper Piagetian theory appears to be a viable foundation for such tests. First, Piaget (1936/1963, 1967/1971, 1972/1977, 1975/1977, 1977) has emphasized the continuous nature of change in a child's competencies, with the descriptions of specific competencies being nothing more than benchmarks in the movement toward more adaptive schemes of environmental interaction. Second, the descriptions of the changes of competencies are clear enough to be operationalized. (Gray, 1973, Note 1; Renner, Note 2). Finally, both the content of children's knowledge that Piaget has investigated and the underlying processes that bring about that knowledge have a direct relation to school taught content. With the above in mind, how is the construction of written Piaget-based standardized tests best approached?

Orientation to the Construction and Validation of a

Piagetian-based Standardized Test

In constructing Piagetian-based standardized tests there are two possible approaches: content conversion and logical operations. Content conversion involves retaining the content of traditional Piagetian physical manipulable

tasks but presenting them as paper-and-pencil questions. For example, a conservation of continuous quantity problem may be pictorially represented and accompanied by an appropriate question which requires a written answer or selection of the correct alternative from a series of alternatives.

Figure 1 is a conservation of continuous quantity problem that was used by

Insert Figure 1 about here

Biological Sciences Curriculum Study (BSCS) to assess basic concrete operational knowledge of junior high school students who were participants in the Human Sciences Program. This question used by BSCS is typical of attempts at converting the content of Piagetian tasks to a written form (See Gray, Hofmann, & Dewitz, Note 3, for an evaluation of the content conversion approach). The BSCS question and all other content conversion approaches have three major disadvantages. First, they focus on the content of a Piaget task and not the logical operations that are necessary for success on the task. It is not the content of Piaget's problems that is important, rather it is the application of specific logical operations to the solution of specific content problems that is important. For example, on the problem in Figure 1, knowing that a student conserved continuous quantity is irrelevant as far as non-science oriented curricula are concerned. What is important is that success on the problem implies that the student can engage in the concrete operational logical operation of Bi-univocal (one-to-one) Multiplication of Relations. If a student is successful on a series of problems which demand Bi-univocal Multiplication of Relations,

then a teacher could be reasonably assured that the student could utilize that operation in solving various concrete (non-abstract) problems. Thus, with the knowledge of the logical competencies of the student, various curricula and/or instruction which incorporate such processes could be designed so that instruction could utilize a student's present level of thinking. However, if the orientation is focused on item content, it becomes difficult, if not impossible, to build instruction on a student's present level of cognitive operations.

The second disadvantage of the content conversion approach is that it is extremely difficult to pictorially represent the content of many Piagetian problems. Figure 1 is a prime example of this. Conservation problems involve a nonessential transformation of some entity, usually something physical, so that the non-transformed and transformed states look different, but remain the same in some important aspect. In Figure 1 the transformation is implicit since the student must "infer" from the picture and text that the bottles contained the same amount of liquid before they were tilted. This requirement of inferring a past situation complicates the problem since the student never saw the situation where the bottles contained the same amount of liquid; and in traditional Piagetian conservation problems, the student first acknowledges that the entities presented are equal in some respect. Similar problems exist for other concrete operational tasks as well as for most formal operational problems (e.g., combination of chemicals; oscillation of a pendulum; conservation of motion in a horizontal plane).

The final disadvantage is shared by both the content conversion and

logical operations approach. That is, both approaches require that a student have a reasonable level of skill in reading. This is a potential problem of all written standardized tests. Unfortunately, attempts at alleviating this problem in written Piaget-based standardized tests have not been very sophisticated or successful (Gray, Hofmann, & Dewitz, Note 3), and consequently it remains a problem.

Utilization of the logical operations approach eliminates the first two disadvantages of the content conversion approach by focusing on the underlying logical processes being assessed and then constructing items which incorporate those processes. Item content and accompanying graphics are then constructed to reflect the logic of the question and not some pre-determined content. The following illustrates the logical operations approach at constructing a Piagetian-based written standardized test of cognitive development.

Item Construction

Item construction is a criterion-referenced process that roughly follows the framework of Nitko's (1970) four criteria for the development of a criterion-referenced instrument. First, different logical operations that describe each developmental level are defined. Inhelder and Piaget (1955/1958, 1959/1969), Piaget (1953/1957), Flavell (1963), and Boyle (1969), provide excellent descriptions of the logical operations of each level. Briefly, preoperations is defined as the absence of concrete operational and formal operational logic. Concrete operations is defined by the operations of the eight groupings: Primary Addition of Classes, Secondary Addition of Classes (Vicariences), Bi-univocal (one-to-one) Multiplication

of Classes, Co-univocal (one-to-many) Multiplication of Classes, Addition of Asymmetrical Relations, Addition of Symmetrical Relations, Bi-univocal Multiplication of Relations, and Co-univocal Multiplication of Relations. Formal operations includes hypothetical-deductive reasoning, propositional thinking, and combinatorial reasoning. For the purpose of illustration, the concrete operation of Addition of Asymmetrical Relations and the formal operational hypothetical-deductive reasoning characteristic of "making correct implications" is used. Table 1 describes the logic

Insert Table 1 about here

for both types of operations with the logic corresponding to the specific items reproduced in Figures 2 and 3. Note that there is an easy transition

Insert Figures 2 and 3 about here

from the Piagetian description of the operations of Addition of Asymmetrical Relations (Inhelder and Piaget, 1959/1969, pp. 247-268) and "making correct implications" (Inhelder and Piaget, 1955/1958, pp. 67-79) to the logic represented in the respective questions.

Second, each logical operation is defined by a set of possible written test items. For example, all items that assess Addition of Asymmetrical Relations have a logical structure identical to that illustrated in Table 1 and are defined as one set; the only difference among the items is their content.

Third, after the items that represent each concrete operation or each formal operation are constructed, a representative sample of items from each operation are selected.

Nitko's (1970) final criterion for a criterion-referenced test is that the obtained score must be capable of expressing objectively and meaningfully the individual's performance characteristics (p. 38). The discussion of this criterion will be made in conjunction with the discussion of the scoring and interpretation of the items.

Scoring and Interpretation

Scoring and the interpretation of scores cannot be separated since how an item is scored determines the interpretation that is used. In scoring Piagetian-based written items the prevailing scoring system is a binary one; (Gray, et al, Note 3) that is, if a subject answers an item correctly, a score of one (1) is assigned and if the item is answered incorrectly, a score of zero (0) is assigned. For example, correctly seriating the squares in the question presented in Figure 2 would receive a score of one and any partial, but correct, seriations would be scored zero. No attempt is made to differentiate between the different types of incorrect responses, and a subject's scores are quantitatively interpreted: The focus is on the number of correct responses only. Consequently, to be considered concrete operational a subject must answer correctly a specified number of items designated as concrete operational and to be considered formal operational a subject must answer correctly a specified number of items designated as formal operational as well as a specified number of items designated as concrete operational (see Gray, et al, Note 3, for a listing of tests utilizing this approach). However, this dichotomous summation approach is not congruent with Piagetian

theory. Recall that Piaget's orientation focuses on a subject's errors, specifically the pattern of errors that a subject makes when giving an incorrect solution to a task. In focusing on a subject's error patterns, the emphasis is on the changing of intra-individual response patterns through time. In such an approach, an incorrect response is more important than a correct response since the emphasis is on the sequence or change in error patterns as an individual moves toward the competency necessary for making a correct response. Presently no attempt has focused on the changing error patterns through time (see Gray, et al, Note 3); however, scoring criteria have been developed which establish the foundation for such an attempt. Tables 2 and 3 are the scoring criteria for the questions illus-

Insert Tables 2 and 3 about here

trated in Figures 2 and 3 respectively. Although the criteria appear to be complicated, they are quite simple and represent an objectification of the "criteria" utilized by Piaget and his collaborators (Inhelder & Piaget, 1959/1969, pp. 247-268, Inhelder & Piaget, 1955/1958, pp. 67-79) to evaluate responses to physical manipulable tasks which require the same logical operations as the items in Figures 2 and 3.

An explanation of both sets of criteria illustrates their relative simplicity. Table 2 specifies the criteria which are used to evaluate children's attempts at seriating a set of objects where the seriation is based on some concrete characteristic which the objects have in common. An individual's score is composed of two parts. The first part involves

the major classification based on a scale ranging from 0 (MISSING DATA) to 8 (FORMAL OPERATIONS II). An indication of these major categories is given by the digit to the left of the decimal point. A score of 2.x indicates that the response to the item illustrated in Figure 2 is classified as preoperational and the digit that is substituted for the x indicates the specific type of response within the major category. For example, if the response is classified as 2.4 it means that one or more "correct" series of 3, 4, or 5 squares is contained in the response. CDHEIFAGB is such a response, where there are four series of five squares (CDHEI, CDHFA, CDHFG, and CHDFB). A score of 4.6 indicates a beginning concrete operational response: all nine squares are sequenced correctly. A response of 1.2 means that there is no attempt to answer the question and this is indicated on the test by such words as "don't know," "can't do," "too hard" or some other writing which indicates that the question is too difficult. If the question is left blank, then the score is 1.1.

Table 3 is an objectification of the criteria Inhelder and Piaget (1955/1958, pp. 67-79) used in describing various types of responses to the pendulum task. In the process of creating the written item, the content of the problem is transformed from one which focuses on the determination of the cause of the change in oscillation frequency of a simple pendulum to one which incorporates the same logic but is more appropriate for presentation in a written form. The first two categories, MISSING DATA and NO ATTEMPT, are the same as those in Table 2. For the remaining categories, the change in response patterns as evidenced by the differences among criteria which define the various response categories illustrates the development of the logical operation of "making a correct implication."

Specifically, the change can be described as a ^{five} ^ step process: PREOPERATIONS - general lack of differentiation among experimental conditions (sentences) or variables; CONCRETE OPERATIONS I - differentiation among experimental conditions (sentences), but no differentiation among the independent variables (color, possession of food, age); CONCRETE OPERATIONS II - differentiation among the independent variables and selection of a combination of variables as determining (co-occurring with) the dependent variable ("mice fighting"); CONCRETE OPERATIONS II-FORMAL OPERATIONS I - selection of one incorrect independent variable; FORMAL OPERATIONS I - selection of correct independent variable. A quick pursual of question 2 in Figure 2 shows that the only variable that consistently co-occurs with the "mice fighting" is that the "mice are old" and the only variable that consisently co-occurs with the "mice not fighting" is that the "mice are not old."

A classification of PREOPERATIONS means that the response is illogical, irrelevant, or unintelligible (2.1) or it lacks any differentiation. This lack of differentiation is made in one of two ways: (1) failure to distinguish among the different experimental conditions either by reproducing all of the sentences or by writing a response that indicates all of the sentences comprise the answer (2.31), or (2) failure to distinguish among the different independent variables by reproducing some combination of all of them or by writing a response that indicates all of the independent variables comprise the answer (2.32).

The classification of CONCRETE OPERATIONS I indicates that a rudimentary differentiation among experimental conditions (sentences) is part of the response. The response focuses on one sentence (4.4x), where the digit that

replaces the x indicates the selected sentence, or a combination of one, two, or three, but not all, sentences. If the response centers on sentences two and three, the classification is 4.53 since in sentence two the dependent variable is positive ("mice fight") and in sentence three the dependent variable is negative ("mice do not fight").

Differentiating among the independent variables and selecting a combination of them is classified as CONCRETE OPERATIONS II. Within this stage there are four major response categories depending on the condition of the dependent variable in the response. For example if the response is "the mice fight when they are not brown and are old," it is classified as 5.6108 for three reasons. First, a combination of two independent variables ("not brown" and "old") is selected as the answer. Second, the condition of the dependent variable is clearly stated ("mice fight") and it is positive. Finally, the combination of independent variables ("not brown and are old") corresponds to one specific subcategory of category 5.61xx. The same logic applies to the remaining three categories of CONCRETE OPERATIONS II, only the dependent variable is stated as being negative (5.62xx), positive and negative (5.63xx), or is not indicated (5.64xx).

A response that focuses on one incorrect independent variable (e.g., "mice do not have food") indicates a transition: CONCRETE OPERATIONS II-FORMAL OPERATIONS I. Other than the refinement of the response from one which focuses on a combination of independent variables to one emphasizing an incorrect independent variable, the logic of the categories is the same for both CONCRETE OPERATIONS II and CONCRETE OPERATIONS II-FORMAL OPERATIONS I.

The final classification is FORMAL OPERATIONS I. To be classified as such, a response must clearly focus on the correct independent variable:

age. A statement such as "mice are old" is scored as 7.81 since the correct independent variable is noted, but there is no mention of the state of the dependent variable. The statement "when the mice are old they fight and when the mice are not old they do not fight" is classified as 7.93.

Note that with this refined classification system it is no longer necessary to go back to the original test to determine why a specific response is classified in a specific way. This specification of refined criteria provides the opportunity to analyze responses on a variety of problems, specifically the error patterns within and between logical operations. If, from an analysis of the error patterns, it can be determined that a group of students make systematic errors when attempting to answer problems which require specific logical operations, then curricula and instruction which require those logical operations for understanding should be altered. Such data can be used for constructing and refining both curricula and various instructional systems, thus raising the possibility of producing curricula that not only meet the criteria of their respective content domains, but also meet the logical capabilities (operations) of the students.

Validation

Ideally, the traditional psychometric approach to validation of a Piagetian-based written test of cognitive development would be longitudinal; that is, the pattern of intra-individual change would be measured by administering the same test items to the same individuals over a period of time. Hopefully, that period of time would be several years. In conjunction with the administration of the written items, the children would

also be given the traditional Piagetian tasks that are logically equivalent to the items on the written test. With responses on both the written items and the traditional Piagetian tasks, the relations among the various measures of the same logical operation can be determined. Unfortunately, no one has performed such a longitudinal analysis.

Practically, the traditional psychometric approach to validation is cross-sectional. That is, subjects of various ages are administered written items and traditional Piagetian tasks, and then the relation among the responses to the written items and the Piaget tasks are calculated. Generally, there is very little attention focused on the logical operations required by the written items and/or the Piagetian tasks (see Gray, et al, Note 3). Rather, the emphasis is on the content conversion approach in the construction of the items and the inclusion of Piagetian tasks that measure concrete operations or formal operations.

A Piagetian approach to validation of the written items can be included in either a longitudinal or cross-sectional approach. That is, after a subject answers a written question, the next question requests that an explanation for the previous question be given. Question 3 in Figure 3 is an attempt at providing a Piagetian method of validation. Although this technique requires that the subject express his thoughts in writing and it does not have the flexibility of the questioning involved in the methode clinique, it does provide valuable information on how individual subjects arrive at their answers. These explanations are evaluated in a manner which is determined by the logic of the written item to which the explanation refers. Table 4 illustrates the scoring criteria for question 3 in

Figure 3.

Insert Table 4 about here

Note that the scoring categories parallel those for question 2 (see Table 3) and the emphasis is on an explanation, not on making the correct answer. With information on both a question requiring the application of a specific logical operation and a succeeding question requiring an explanation of the judgment, data can be gathered that indicates whether the acquisition of a specific logical operation is beginning or has been reasonably finalized. If the judgment on question 2 (see Figure 2) is correct, but the explanation is not of formal operational quality then the acquisition of the operation has not been finalized. When there is a formal operational response to both questions and this is repeated for several similar sets of questions, then it may be concluded that the acquisition of the operation is finalized. The distinctions among the different points on a continuum of acquiring an operation ^{are} ~~is~~ important since more can be expected from a student who has consolidated the acquisition of an operation versus a student who is just beginning acquisition of an operation. These distinctions are manifested in the stability and generalizability of responses since a student who has finalized acquisition tends to produce more stable and generalizable responses to various problems which require the operation for success than a student who is just beginning acquisition of the operation.

Effects of the Use of a Piagetian-based Standardized Test

Any form of evaluation will have a variety of effects on numerous aspects of the schooling process. When a change in evaluation is invoked not only will there be effects on the evaluation process itself, but there will also be effects on use of the results of the evaluation process.

Relative to the process of evaluation itself, if the process to be used is one of measuring generalized developmental levels there will be no change in the process of evaluation when compared to traditional empirically derived standardized tests. Simply put, the evaluation can take place under specialized circumstances. Children can be given the examination on certain days at specified times. However, if developmental levels are incorporated into standardized tests of content, then a radical change in the process of evaluation will occur. Specifically, children will not be evaluated under special circumstances. Evaluation will not be something special. Rather, it will be an integral part of the curricula, and it will be dependent upon the construction of evaluation devices that accurately reflect specified developmental levels as well as specific content. Thus, any change that would take place in the process of evaluation will only occur if developmental levels are built into the actual curricula such as workbooks, worksheets, summative and formative tests, etc.

More important than the evaluation process itself is the effect of the results of evaluation. Regardless, of whether a generalized test or a logically based test for a specific content area is used, the major change that must occur is with people: specifically, teachers, curriculum makers, and evaluators. First and foremost they would have to understand development

to be able to construct such tests, evaluate them appropriately, and understand what the results of such tests mean in terms of suggestions for specific instructional procedures or specific instructional content for particular children. Unfortunately, this is something that will not occur in the very near future. Most educators are notoriously ignorant of what they are assessing when they evaluate children. About the only thing that could be said is that they implicitly swear allegiance to the cumulative quantitative model of learning. There appears to be no realization that learning involves qualitative changes. To have the impact that such tests should have on the educational process would necessitate a radical reorganization of teacher education and educational research. No longer would there be a heavy emphasis on traditional methods courses for teachers or statistical models based on the "simplicity" of a normal curve distribution for educational researchers; rather there would be an emphasis on non-behavioristic learning theory, cognitive processes, and development. Once prospective teachers and researchers have demonstrated a thorough knowledge in these areas, then they could be introduced to various instructional methodologies that should be presented as possibilities that can aid children in moving from one level of competence to another and/or they can be introduced to statistical models that are more appropriate for evaluating development.

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Footnotes

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Table 1

Description of the Logical Operations Included in the Test Items
Reproduced in Figures 2 and 3

Level ^a	Operation	Item	Logic
CI	Addition of A symmetrical Relations	1	$C < D < H < F < B < G < A < E < I^b$
FI	Make True Implication	2	$\bar{A} \cdot \bar{C} \cdot B \cdot \bar{D}^c$ $D \cdot \bar{B} \cdot C \cdot A$ $\bar{C} \cdot \bar{D} \cdot A \cdot \bar{B}$ $B \cdot \bar{A} \cdot D \cdot C$ $\therefore [C (A \vee B) \leftrightarrow D] \cdot [\bar{C} (A \vee B) \leftrightarrow \bar{D}]$

^aCI = beginning concrete operations; FI = beginning formal operations.

^b< = "smaller than"

^c· = "and"; $\vee$ = "or"; $\therefore$ = "therefore"; $\leftrightarrow$ = "implies and is implied by"; $\bar{}$ = "not"; A = mice are brown; B = mice have food; C = mice are old; D = mice fight

Table 2

Scoring Criteria for Tasks Requiring the Concrete Operation of
 "Addition of Asymmetrical Relations"^a

Score	Classification	Criterion ^b
0.0	MISSING DATA	
1.0	NO ATTEMPT	
1.1		No response/Blank
1.2		"Don't know"/"Can't do"/"Too hard"/ etc
2.0	PREOPERATIONS	
2.1		Illogical/Irrelevant/Unintelligible
2.2		Alphabetic listing (i.e., ABCD. . .) of letters representing squares to be seriated
2.3		One or more reversed series of three, four, or five squares
2.4		One or more "correct" series of three, four, or five squares
3.0	PREOPERATIONS- CONCRETE OPERATIONS I	
3.3		One or more reversed series of six, seven, or eight squares

Table 2 (Cont'd)

Score	Classification	Criterion ^b
3.4		One or more "correct" series of six, seven, or eight squares
3.5		All eight squares "correctly" reversed
4.0	CONCRETE OPERATIONS I	
4.6		Complete correct series of nine squares

^aA complete description of the various concrete operations and formal operations may be found in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

^bDerived from a more refined, complete, and general set which will appear in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

Table 3
 Scoring Criteria for Tasks Requiring the Formal Operation
 of "Making a Correct Implication"^a

Score	Classification	Criterion ^b
0.0	MISSING DATA	
1.0	NO ATTEMPT	
1.1		No response/Blank
1.2		"Don't know"/"Can't do"/"Too hard"/ etc
2.0	PREOPERATIONS	
2.1		Illogical/Irrelevant/Unintelligible
2.3		Does not differentiate:
2.31		Between sentences
2.32		Between independent variables ^c
4.0	CONCRETE OPERATIONS I	
4.4		Selects one sentence
4.41		First
4.42		Second
4.43		Third
4.44		Fourth
4.5		Selects a combination of sentences where the dependent variable ^d is
4.51		Positive
4.52		Negative

Table 3 (Cont'd)

Score	Classification	Criterion ^b
4.53		Positive and negative
5.0	CONCRETE OPERATIONS II	
5.61		Selects a combination of independent variables or their negation <u>and</u> indicates that when they occur the dependent variable is positive <u>or</u> indicates that when the dependent variable is positive a combination of independent variables or their negation occurs
5.6101		Mice are brown and mice are not brown
5.6102		Mice are brown and mice have food
5.6103		Mice are brown and mice do not have food
5.6104		Mice are brown and mice are old
5.6105		Mice are brown and mice are not old
5.6106		Mice are not brown and mice have food
5.6107		Mice are not brown and mice do not have food
5.6108		Mice are not brown and mice are old
5.6109		Mice are not brown and mice are not old

Table 3 (Cont'd)

Score	Classification	Criterion ^b
5.6110		Mice have food and mice do not have food
5.6111		Mice have food and mice are old
5.6112		Mice have food and mice are not old
5.6113		Mice do not have food and mice are old
5.6114		Mice do not have food and mice are not old
5.6115		Mice are old and mice are not old
5.62		Selects a combination of independent variables or their negation <u>and</u> indicates that when they occur the dependent variable is negative <u>or</u> indicates that when the dependent variable is negative a combination of independent variables or their negation occurs
5.6201		Mice are brown and mice are not brown
5.6202		Mice are brown and mice have food
5.6203		Mice are brown and mice do not have food

Table 3 (Cont'd)

Score	Classification	Criterion ^b
5.6204		Mice are brown and mice are old
5.6205		Mice are brown and mice are not old
5.6206		Mice are not brown and mice have food
5.6207		Mice are not brown and mice do not have food
5.6208		Mice are not brown and mice are old
5.6209		Mice are not brown and mice are not old
5.6210		Mice have food and mice do not have food
5.6211		Mice have food and mice are old
5.6212		Mice have food and mice are not old
5.6213		Mice do not have food and mice are old
5.6214		Mice do not have food and mice are not old
5.6215		Mice are old and mice are not old
5.63		Selects a combination of independ- ent variables or their negation <u>and</u>

Table 3 (Cont'd)

Score	Classification	Criterion ^b
		indicates that when they occur the dependent variable is positive and negative <u>or</u> indicates that when the dependent variable is positive and negative a combination of independent variables or their negation occurs
5.6301		Mice are brown and mice are not brown
5.6302		Mice are brown and mice have food
5.6303		Mice are brown and mice do not have food
5.6304		Mice are brown and mice are old
5.6305		Mice are brown and mice are not old
5.6306		Mice are not brown and mice have food
5.6307		Mice are not brown and mice do not have food
5.6308		Mice are not brown and mice are old
5.6309		Mice are not brown and mice are not old

Table 3 (Cont'd)

Score	Classification	Criterion ^b
5.6310		Mice have food and mice do not have food
5.6311		Mice have food and mice are old
5.6312		Mice have food and mice are not old
5.6313		Mice do not have food and mice are old
5.6314		Mice do not have food and mice are not old
5.6315		Mice are old and mice are not old
5.64		Selects a combination of independent variables or their negation but does not indicate any state of the dependent variable
5.6401		Mice are brown and mice are not brown
5.6402		Mice are brown and mice have food
5.6403		Mice are brown and mice do not have food
5.6404		Mice are brown and mice are old
5.6405		Mice are brown and mice are not old

Table 3 (Cont'd)

Score	Classification	Criterion ^b
5.6406		Mice are not brown and mice have food
5.6407		Mice are not brown and mice do not have food
5.6408		Mice are not brown and mice are old
5.6409		Mice are not brown and mice are not old
5.6410		Mice have food and mice do not have food
5.6411		Mice have food and mice are old
5.6412		Mice have food and mice are not old
5.6413		Mice do not have food and mice are old
5.6414		Mice do not have food and mice are not old
5.6415		Mice are old and mice are not old
6.0	CONCRETE OPERATIONS II- FORMAL OPERATIONS I	

Table 3 (Cont'd)

Score	Classification	Criterion ^b
6.71		Selects one incorrect independent variable or its negation <u>and</u> indicates that when it occurs the dependent variable is positive <u>or</u> indicates that when the dependent variable is positive one incorrect independent variable or its negation occurs
6.711		Mice are brown
6.712		Mice are not brown
6.713		Mice have food
6.714		Mice do not have food
6.72		Selects one incorrect independent variable or its negation <u>and</u> indicates that when it occurs the dependent variable is negative <u>or</u> indicates that when the dependent variable is negative one incorrect independent variable or its negation occurs
6.721		Mice are brown
6.722		Mice are not brown

Table 3 (Cont'd)

Score	Classification	Criterion ^b
6.723		Mice have food
6.724		Mice do not have food
6.73		Selects one incorrect independent variable or its negation <u>and</u> indicates that when it occurs the dependent variable is positive and negative <u>or</u> indicates that when the dependent variable is positive and negative one incorrect independent variable or its negation occurs
6.731		Mice are brown
6.732		Mice are not brown
6.733		Mice have food
6.734		Mice do not have food
6.74		Selects one incorrect independent variable or its negation but does not indicate any state of the dependent variable
6.741		Mice are brown
6.742		Mice are not brown
6.743		Mice have food
6.744		Mice do not have food

Table 3 (Cont'd)

Score	Classification	Criterion ^b
7.0	FORMAL OPERATIONS I	
7.81		Selects correct independent variable (mice are old) but does not indicate any state of the dependent variable
7.82		Selects the negation of the correct independent variable (mice are not old) but does not indicate any state of the dependent variable
7.83		Selects correct independent variable (mice are old) <u>and</u> the negation of the correct independent variable (mice are not old) but does not indicate any state of the dependent variable
7.91		Selects correct independent variable (mice are old) <u>and</u> indicates that when it occurs the dependent variable is positive <u>or</u> indicates that when the dependent variable

Table 3 (Cont'd)

Score	Classification	Criterion ^b
7.92		is positive the correct independent variable (mice are old) occurs Selects the negation of the correct independent variable (mice are not old) <u>and</u> indicates that when it occurs the dependent variable is negative <u>or</u> indicates that when the dependent variable is negative the negation of the correct independent variable (mice are not old) occurs
7.93		Selects correct independent variable (mice are old) <u>and</u> indicates that when it occurs the dependent variable is positive <u>AND</u> selects the negation of the correct independent variable (mice are not old) <u>and</u> indicates that when it occurs the dependent variable is negative <u>OR</u> indicates that when the dependent variable is positive the correct independent variable (mice

Table 3 (Cont'd)

Score	Classification	Criterion ^b
		are old) occurs <u>AND</u> when the dependent variable is negative the negation of the correct independent variable (mice are not old) occurs.

^aA complete description of the various concrete operations and formal operations may be found in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

^bDerived from a more refined, complete, and general set which will appear in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

^cColor; possession of food; age.

^dFighting or not.

Table 4

Scoring Criteria for Tasks Requiring an Explanation of an Answer
to a Question Requiring the Formal Operation
of "Making a Correct Implication"^a

Score	Classification	Criterion ^b
0.0	MISSING DATA	
1.0	NO ATTEMPT	
1.1		No response/Blank
1.2		"Don't know"/"Can't do"/"Too hard"/ etc
2.0	PREOPERATIONS	
2.1		Illogical/Irrelevant/Unintelligible
2.2		Refers to personal knowledge
2.21		Makes up story
2,22		"Guessed"
2.23		"Process of elimination"
2.24		"Only possible answer"/"Self-explan- atory"
2.3		Does not differentiate:
2.31		Between sentences
2.32		Between independent variables ^c
4.0	CONCRETE OPERATIONS I	
4.4		<u>Explanation</u> focuses on one sentence

Table 4 (Cont'd)

Score	Classification	Criterion ^b
4.5		<u>Explanation</u> focuses on a combination of sentences
5.0	CONCRETE OPERATIONS II	
5.61		<u>Explanation</u> indicates that when a combination of independent variables or their negation occurs the dependent variable ^d is positive <u>or</u> when the dependent variable is positive a combination of independent variables or their negation occurs
5.62		<u>Explanation</u> indicates that when a combination of independent variables or their negation occurs the dependent variable is negative <u>or</u> when the dependent variable is negative a combination of independent variables or their negation occurs
5.63		<u>Explanation</u> indicates that when a combination of independent variables or their negation occurs the

Table 4 (Cont'd)

Score	Classification	Criterion ^b
5.64		the dependent variable is positive and negative <u>or</u> when the dependent variable is positive and negative a combination of independent variables occurs <u>Explanation</u> indicates that a combination of independent variables or their negation occurs but there is no indication of any state of the dependent variable
6.0	CONCRETE OPERATIONS II- FORMAL OPERATIONS I	
6.71		<u>Explanation</u> indicates that when one incorrect independent variable or its negation occurs the dependent variable is positive <u>or</u> when the dependent variable is positive one incorrect independent variable or its negation occurs
6.72		<u>Explanation</u> indicates that when one incorrect independent variable or

Table 4 (Cont'd)

Score	Classification	Criterion ^b
6.73		its negation occurs the dependent variable is negative <u>or</u> when the dependent variable is negative one incorrect independent variable or its negation occurs <u>Explanation</u> indicates that when one incorrect independent variable or its negation occurs the dependent variable is positive and negative <u>or</u> when the dependent variable is positive and negative one incorrect independent variable occurs
6.74		<u>Explanation</u> indicates that one incorrect independent variable or its negation occurs but there is no indication of any state of the dependent variable
7.0	FORMAL OPERATIONS I	
7.81		"Only one in common"
7.91		<u>Explanation</u> indicates that when the correct independent variable is

Table 4 (Cont'd)

Score	Classification	Criterion ^b
7.92		positive the dependent variable is positive <u>or</u> when the dependent variable is positive the correct independent variable is positive <u>Explanation</u> indicates that when the correct independent variable is negative the dependent variable is negative <u>or</u> when the dependent variable is negative the correct independent variable is negative
7.93		<u>Explanation</u> indicates that when the correct independent variable is positive the dependent variable is positive <u>and</u> when the correct independent variable is negative the dependent variable is negative <u>or</u> when the dependent variable is positive the correct independent variable is positive <u>and</u> when the dependent variable is negative the correct independent variable is negative

Table 4 (Cont'd)

Score	Classification	Criterion ^b
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^aA complete description of the various concrete operations and formal operations may be found in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

^bDerived from a more refined, complete, and general set which will appear in W. M. Gray, Standardized Scoring Criteria for Measures of Piagetian Logical Operations. In preparation.

^cColor; possession of food; age.

^dFighting or not.

Figure Captions

Figure 1. "How Is Your Logic?" Experimental Edition, May 1974, Form A, Question 14. From The Human Sciences Program. Copyright 1974 by Biological Sciences Curriculum Study. Reprinted by permission.

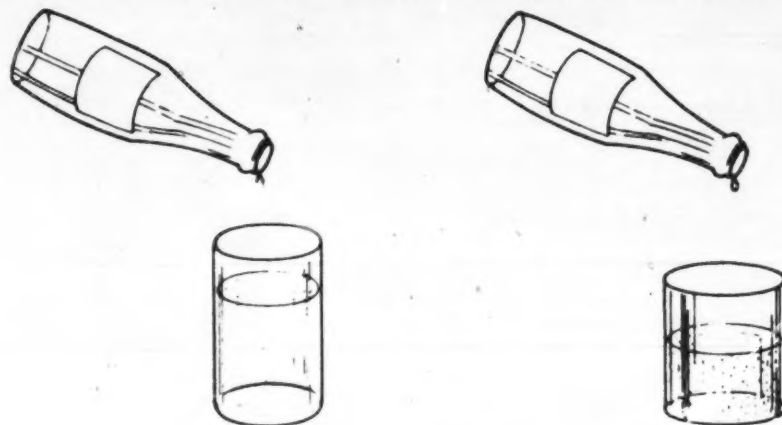
Figure 2. "How Is Your Logic?" Form A, Question 1. From The Human Sciences Program. Copyright 1976 by Biological Sciences Curriculum Study. Reprinted by permission.

Figure 3. "How Is Your Logic?" Form A, Questions 2 and 3. From The Human Sciences Program. Copyright 1976 by Biological Sciences Curriculum Study. Reprinted by permission.

14.

44

SUE AND KAREN WANTED A BOTTLE OF ROOT BEER. THEIR MOTHER POURED ONE BOTTLE INTO A TALL SKINNY GLASS AND THE OTHER BOTTLE INTO A SHORT FAT GLASS AS SHOWN BELOW.



DOES ONE GLASS HAVE MORE ROOT BEER IN IT THAN THE OTHER?

THE TALL GLASS HAS MORE IN IT.

THE SHORT GLASS HAS MORE IN IT.

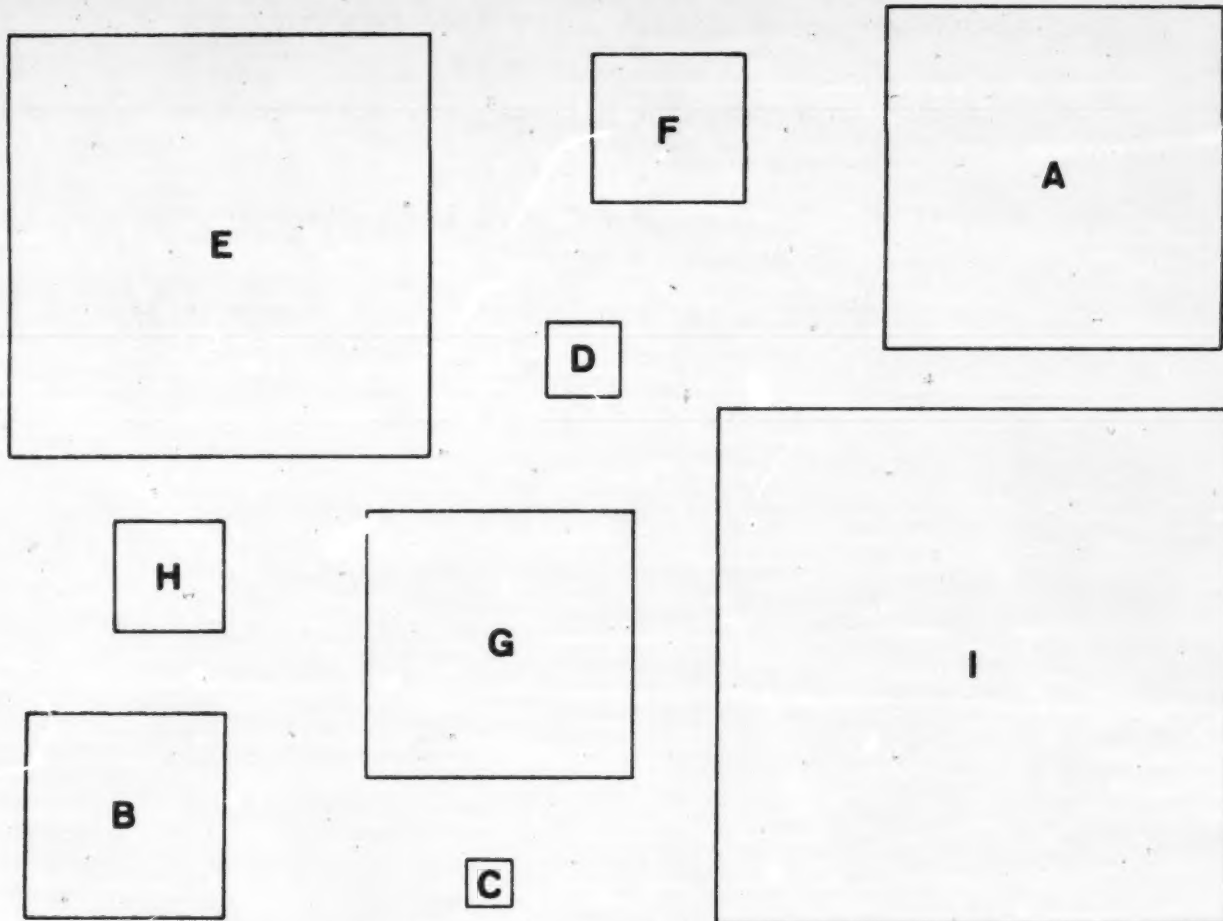
THEY BOTH HAVE THE SAME AMOUNT.

I DON'T KNOW.

MARK AN X ON YOUR CHOICE.

WHY DID YOU CHOOSE THE ANSWER YOU MARKED?

1.



ON THE LINES BELOW, WRITE THE LETTERS OF THE SQAURES FROM
SMALLEST TO LARGEST.

_____ (SMALLEST)

_____ (LARGEST)

2. ALL OF THE FOLLOWING SENTENCES ARE TRUE. WHAT DETERMINES WHETHER OR NOT THE MICE WILL FIGHT WITH EACH OTHER?

THE MICE ARE NOT BROWN; THE MICE ARE NOT OLD; THE MICE HAVE FOOD; THE MICE DO NOT FIGHT.

THE MICE FIGHT; THE MICE DO NOT HAVE FOOD; THE MICE ARE OLD; THE MICE ARE BROWN.

THE MICE ARE NOT OLD; THE MICE DO NOT FIGHT; THE MICE ARE BROWN; THE MICE DO NOT HAVE FOOD.

THE MICE HAVE FOOD; THE MICE ARE NOT BROWN; THE MICE FIGHT; THE MICE ARE OLD.

ANSWER:

3. EXPLAIN YOUR ANSWER: